# Planetary Science Context for EVA

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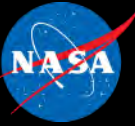Jacob Bleacher
NASA GSFC

Kristen John
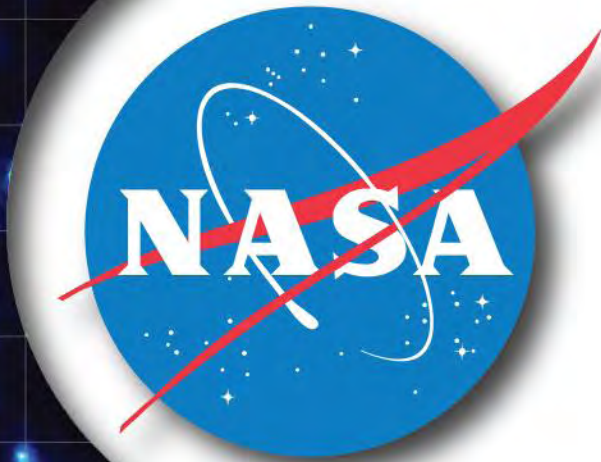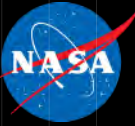Astromaterials Research and Exploration Science/NASA JSC

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# Scientific Drivers for EVA

- Geologic fieldwork is loosely defined as the work necessary to:
    - Determine the spatial distribution, age, and attitude of the rock types in an area
    - Document those structures that have deformed or cut those units
    - Determine the processes that led to the emplacement of these rocks, and have subsequently modified them
    - Collect representative and targeted sampling in the area

- Terrestrial fieldwork traditionally includes multiple field campaigns and relatively high potential sampling volumes

- Planetary field geology introduces complexities but the basic process remains the same
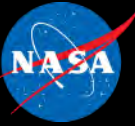
# CONDUCTING GEOLOGIC FIELDWORK

# Scientific Analogs


K10 Rover Mission

Haughton Mars Project, Canada


DRATS

San Francisco Volcanic Field, AZ
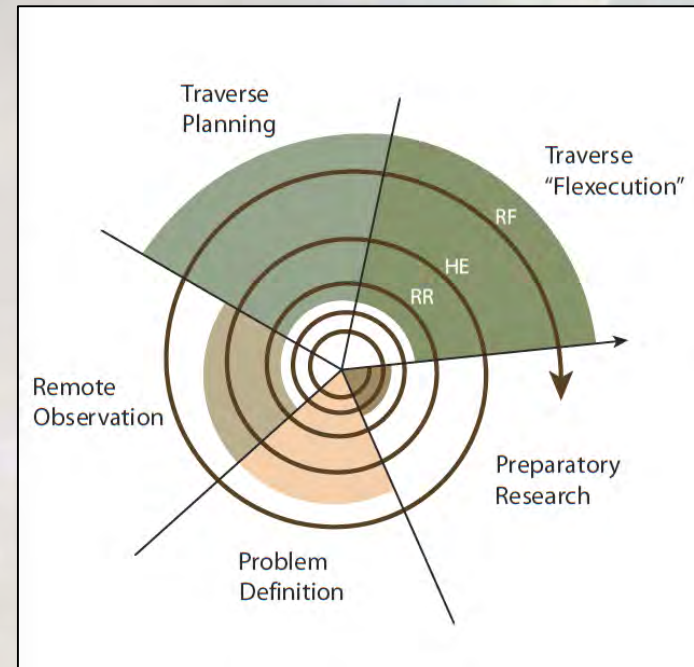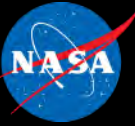
- Multiple definitions of analogs
  - Scientific/Process-driven
  - Science Operations
  - Technology Development
- Scientific analogs enable  process-driven questions, and can be used to understand analogous processes on other planetary surfaces
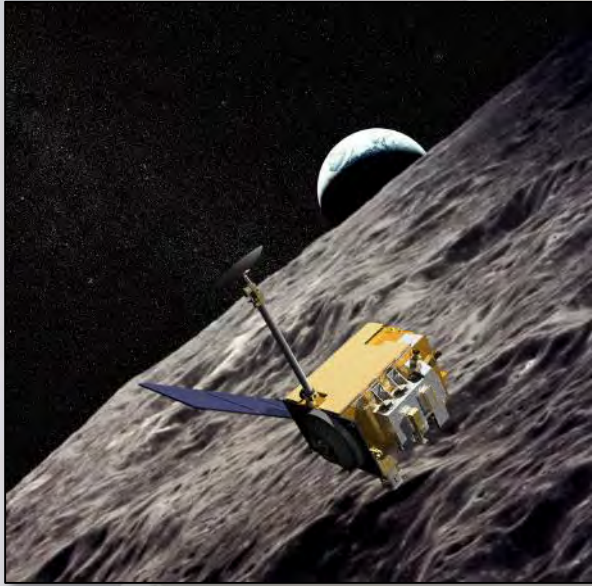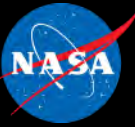
# Flexecution
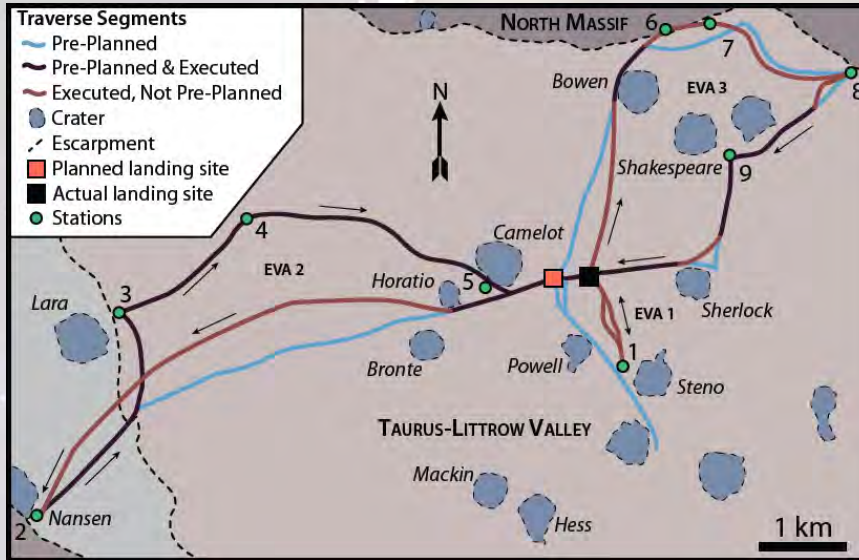


*Hodges and Schmitt*, 2011

- Initial traverse plan based on remote sensing data
- Real-time data return from observations and *in situ* analysis leads to "flexible execution" of initial traverse plan
- Training, technology, and operational concept development should incorporable this flexibility

# Scientific Drivers for Planetary Exploration



LRO: NASA GSFC Conceptual Images Lab

MSL: NASA/JPL-Caltech/MSSS

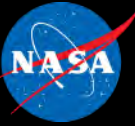OSIRIS-REX: NASA/Univ. AZ/Lockheed Martin

- Massive advancements made since Apollo surface missions, but there are still a number of outstanding science questions across all potential targets of interest for human exploration

- Areas of interest include geology, geophysics, geochemistry, atmospheres, life-related chemistry, etc.
  – Varying levels of human interaction
  – Astrobiology: Planetary Protection

# Science and Exploration
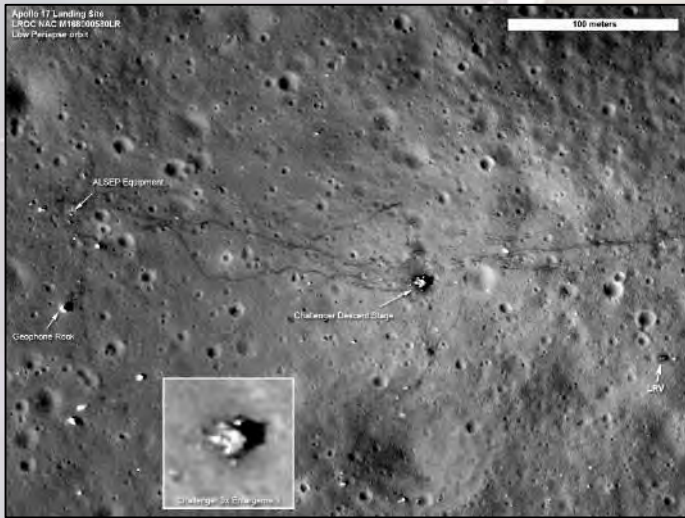


Apollo 17 Landing Site
NASA/GSFC/ASU



*Image 400m across*
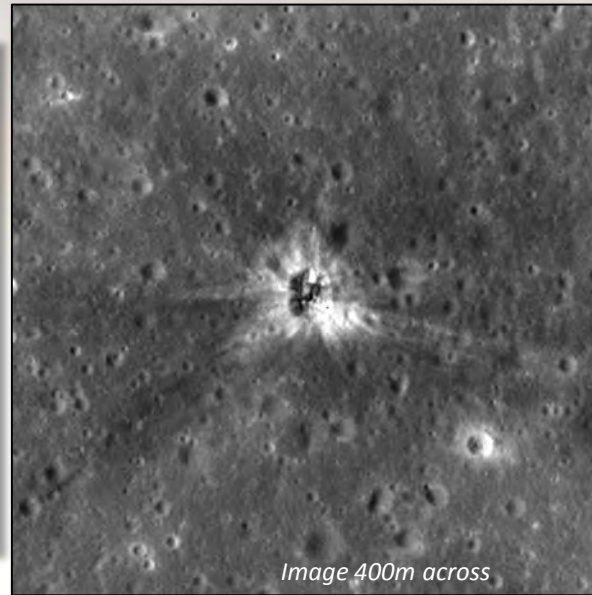
Apollo 16 S-IVB Impact Crater
NASA/GSFC/ASU
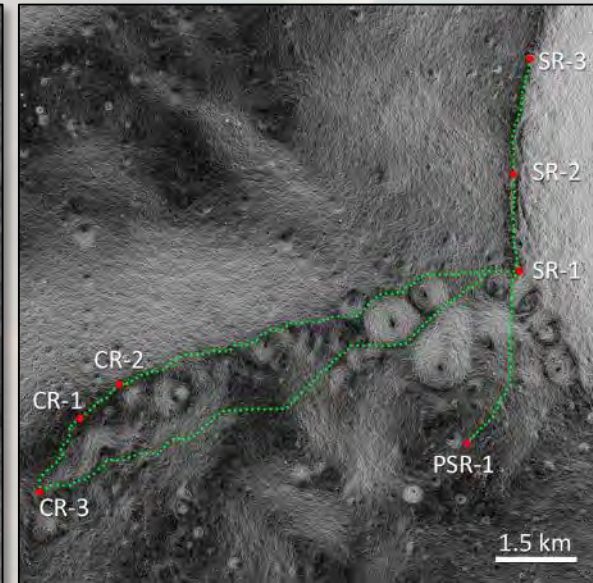


LRO Traverse Planning
*Speyerer et al.,* 2016

- Lunar Reconnaissance Orbiter (LRO) jointly funded by ESMD/SMD
- Initially operated to select landing sites for future crewed missions before being transferred for science operations
- LRO Instrumentation: CRaTER (Cosmic Ray Telescope for the Effects of Radiation), DLRE (Diviner Lunar Radiometer Experiment), LAMP (Lyman-Alpha Mapping Project), LEND (Lunar Exploration Neutron Detector), LROC (Lunar Reconnaissance Orbiter Camera), LOLA (Lunar Orbiter Laser Altimeter), Mini-RF (Miniature Radio Frequency)

# Science Integration into Human Exploration

- Goal: To integrate science into human exploration initiatives, ultimately achieving early scientific integration and concepts/prototype testing that will increase the scientific return, reduce the risk, and improve the affordability of deep-space missions

- Participants:
  - JSC/ARES/Astromaterials
  - GSFC/Solar System Exploration Division

- Building off collaborations built over a decade of analog testing (i.e. D-RATS, NEEMO, RIS$^4$E SSERVI, etc)

- Ex. OSIWEG and Science and Tools Collaboration Group

# SCIENCE AND HUMAN EXPLORATION INTEGRATION
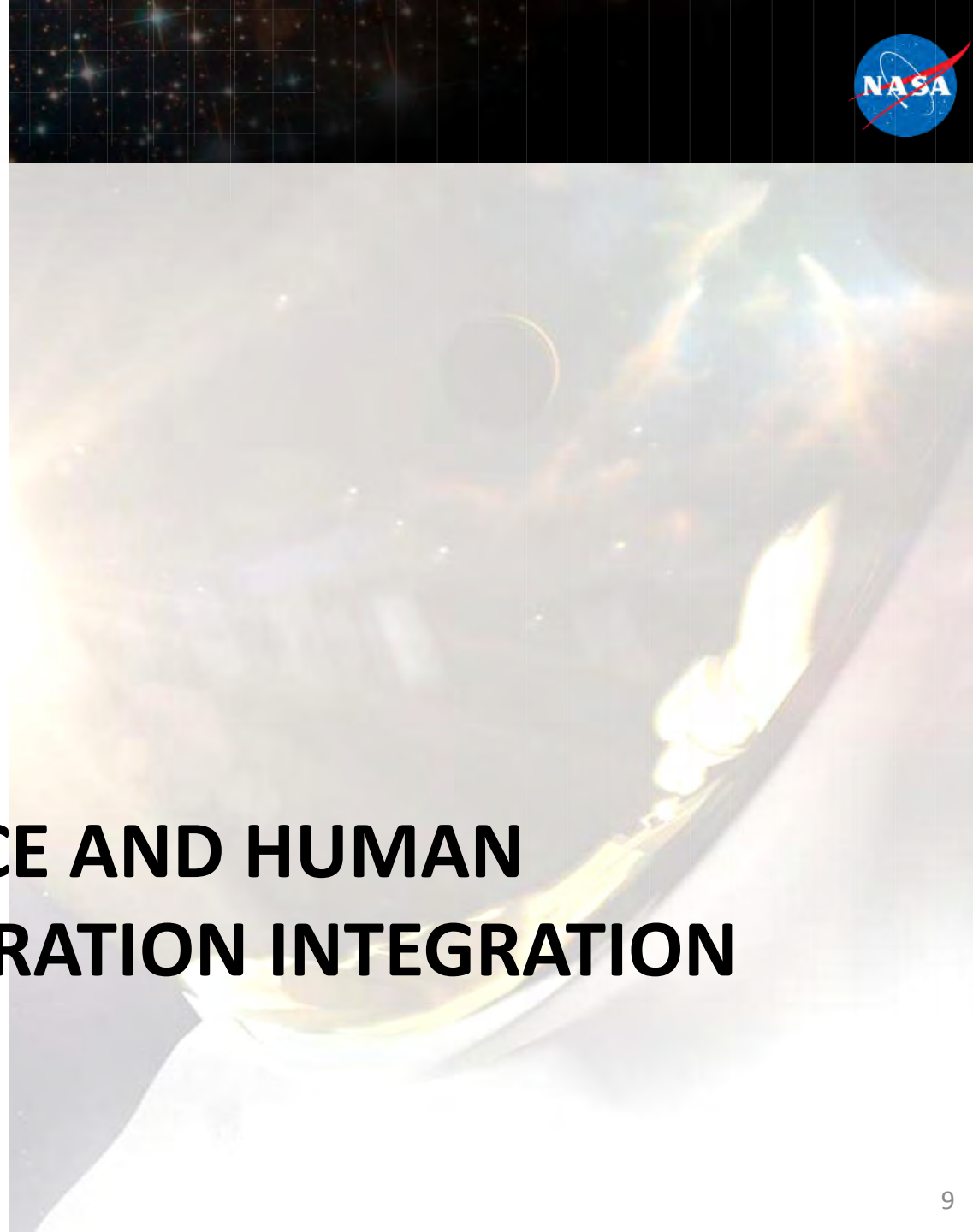
# Science Integration into Human Exploration
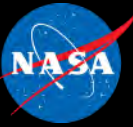
Leverage Knowledge and Experience From:

### Apollo Training and Lessons Learned
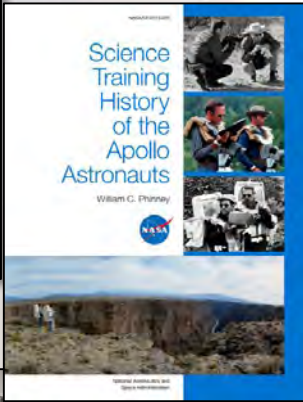
### Field Experience
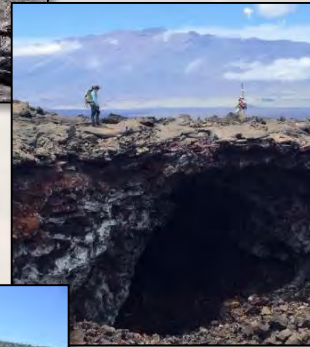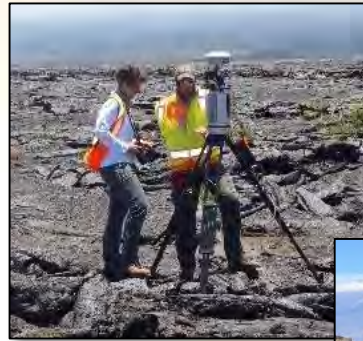
### Robotic Operations and Analog Missions
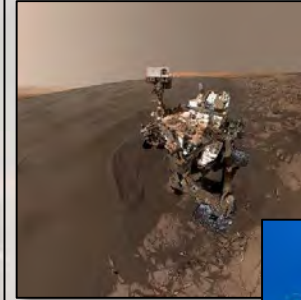
# Incorporating Science Into Exploration


*Analogs for Planetary Exploration*


RIS⁴E SSERVI

Science

Instrument Development

Recommendations
For Future Missions


Gale Crater, Mars
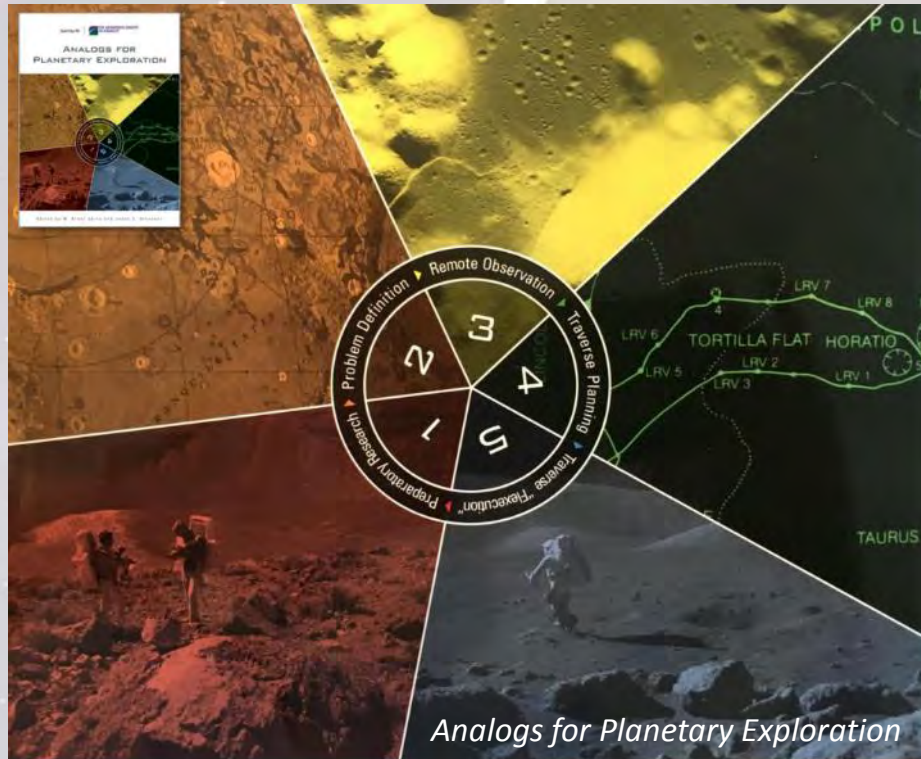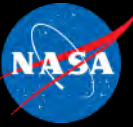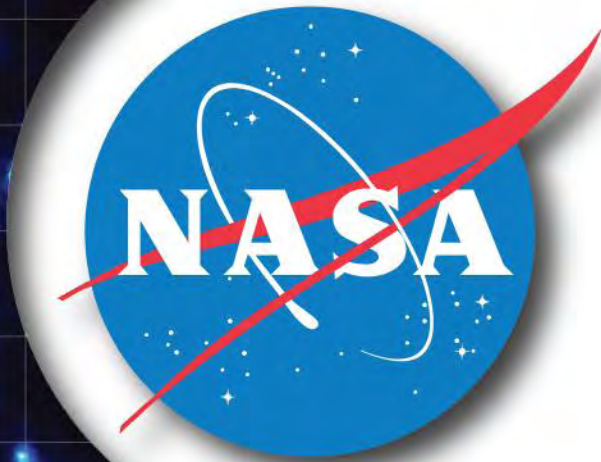
# STRATEGIC KNOWLEDGE GAPS

# Planetary Science Analysis Groups

- Analysis Groups
  - Organization of science sub communities into different groups based on subject area
  - AGs identify how far we've come, where we're going, and develop and maintain outstanding science questions
- MEPAG – Mars Exploration Program Analysis Group
- LEAG – Lunar Exploration Analysis Group
- SBAG – Small Bodies Assessment Group
- CAPTEM – Curation and Analysis Planning Team for Extraterrestrial Materials
- VEXAG – Venus Exploration Analysis Group

# Strategic Knowledge Gaps

- After major outstanding questions are decided, the AGs compile Strategic Knowledge Gaps (SKGs) to direct future activities and identify areas for growth

- Strategic Action Groups are then assembled to address specific SKGs
  - MEPAG: HSO-SAG
  - LEAG: HEP-G
  - LEAG: GAT SAT
  - SBAG: SKG SAT

- AGs with overlap into human exploration destinations (MEPAG, LEAG, SBAG) integrate exploration objectives into their charters

1. **Launch Date**: Date of launch of a human mission to the martian surface: 2035.

2. **Precursor Robotic Missions**: Assume that a program of robotic missions to Mars would take place before the first human mission, with a mixture of both scientific (MEPAG Goals 1-3) and preparation (MEPAG Goal 4) objectives. Thus, relative to what we know today, at the time of the first human mission our knowledge of Mars would be incrementally improved by the results of these missions.

3. **Human Missions**: Assume that more than one mission (nominally 4 people per crew) will visit the same surface location at different times and each crew will spend 300-500 sols during their mission on the surface of Mars.

4.  **<u>Crew Capabilities</u>**: Assume that the following capabilities are available to the crew during their time on the martian surface:
    a.   Ability to traverse to sites at least 100 km away from the landing site.
    b.   Laboratory facilities (of as-yet undefined functionality) located in a pressurized habitat.
    c.   Multiple Extravehicular Activities (EVA) to gather samples, document visited sites, perform basic analyses, and emplace instrumentation.

5.  **<u>Objectives</u>**: Assume that the objectives of possible human missions to Mars can be organized into three categories: i) Mars planetary science objectives, ii) scientific objectives not related to Mars, and iii) non-scientific objectives. This SAG is asked to limit its attention to only the first of these categories (but an actual future mission would likely have objectives in all three areas).

***Note:** Although Planetary Protection considerations will be important to the planning of eventual human missions, the site criteria derived here are evaluated from science factors only.*

# HSO-SAG

Forecast of 2030s' Objectives:



Top-Level elements unlikely to change significantly by 2030

Some change likely (but hard to predict specifics)

Significant change certain

MEPAG's 4-Tiered Hierarchy

Pyramid levels from top to bottom: Goals (with tiers Life, Climate, Geology, Humans), Objectives, Sub-Objectives, Investigations
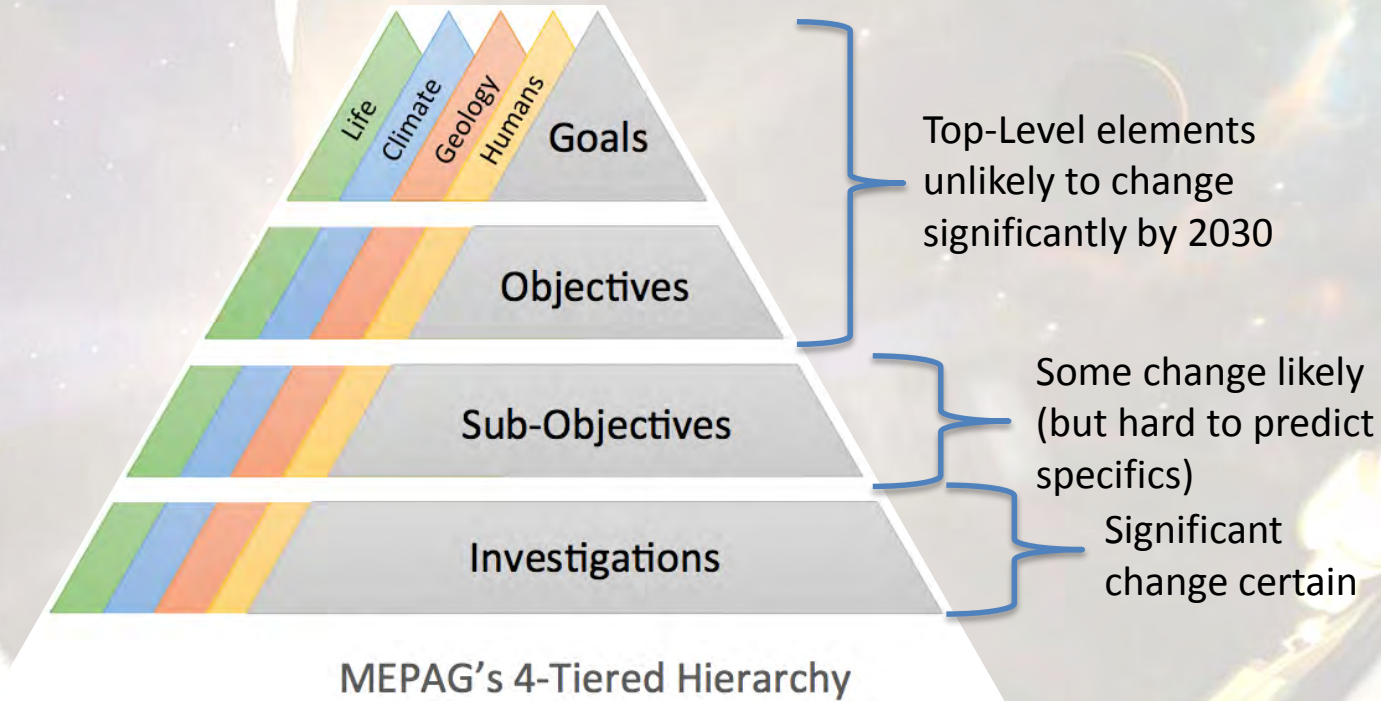
A proximal human would add greatest value to science in:
1. Establishing geologic context (field observations and field measurements)
2. Sampling
3. Sample prep and analysis in a habitat-based laboratory
4. Field investigations/analyses
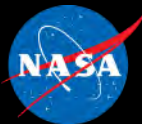
## High-Level MEPAG Science Goals and Objectives

| | |
|---|---|
| **GOAL I: Determine if Mars ever supported life.** | A. Determine if environments having high potential for prior habitability and preservation of biosignatures contain evidence of past life. |
| | B. Determine if environments with high potential for current habitability and expression of biosignatures host evidence of extant life. |
| **GOAL II: Understand the processes and history of climate on Mars.** | A. Characterize the state of the present climate of Mars' atmosphere and surrounding plasma environment, and the underlying processes, under the current orbital configuration. |
| | B. Characterize the history of Mars' climate in the recent past, and the underlying processes, under different orbital configurations. |
| | C. Characterize Mars' ancient climate and underlying processes. |
| **GOAL III: Understand the origin and evolution of Mars as a geological system.** | A. Document the geologic record preserved in the crust and interpret the processes that have created it. |
| | B. Determine the structure, composition, and dynamics of the Martian interior and how it has evolved. |
| | C. Determine the manifestations of Mars' evolution as recorded by its moons. |

HSO-SAG
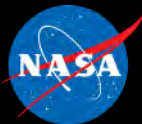
## High-Level MEPAG Sub-Objectives

| GOAL | Sub-Objectives |
|---|---|
| **GOAL I: Determine if Mars ever supported life.** | **A1.** Identify environments that were habitable in the past, and characterize conditions and processes that may have influenced the degree or nature of habitability therein. |
| | **A2.** Assess the potential of conditions and processes to have influenced preservation or degradation of biosignatures and evidence of habitability, from the time of formation to the time of observation. Identify specific deposits and subsequent geological conditions that have high potential to have preserved individual or multiple types of biosignatures. |
| | **A3.** Determine if biosignatures of a prior ecosystem are present. |
| | **B1.** Identify environments that are presently habitable, and characterize conditions and processes that may influence the nature or degree of habitability therein. |
| | **B2.** Assess the potential of specific conditions and processes to affect the expression and/or degradation of signatures of extant life. |
| | **B3.** Determine if biosignatures of an extant ecosystem are present. |
| **GOAL II: Understand the processes and history of climate on Mars.** | **A1.** Constrain the processes that control the present distributions of dust, water, and carbon dioxide in the lower atmosphere, at daily, seasonal and multi-annual timescales. |
| | **A2.** Constrain the processes that control the dynamics and thermal structure of the upper atmosphere and surrounding plasma environment. |
| | **A3.** Constrain the processes that control the chemical composition of the atmosphere and surrounding plasma environment. |
| | **A4.** Constrain the processes by which volatiles and dust exchange between surface and atmospheric reservoirs. |
| | **B1.** Determine how the chemical composition and mass of the atmosphere has changed in the recent past. |
| | **B2.** Determine the record of the recent past that is expressed in geological and mineralogical features of the polar regions. |
| | **B3.** Determine the record of the climate of the recent past that is expressed in geological and mineralogical features of low- and mid-latitudes. |
| | **C1.** Determine how the chemical composition and mass of the atmosphere have evolved from the ancient past to the present. |
| | **C2.** Find and interpret physical and chemical records of past climates and factors that affect climate. |
| | **C3.** Determine present escape rates of key species and constrain the processes that control them. |
| **GOAL III: Understand the origin and evolution of Mars as a geological system.** | **A1.** Identify and characterize past and present geologic environments and processes relevant to the crust. |
| | **A2.** Determine the absolute and relative ages of geologic units and events through Martian history. |
| | **A3.** Constrain the magnitude, nature, timing, and origin of past planet-wide climate change. |
| | **B1.** Identify and evaluate manifestations of crust-mantle interactions. |
| | **B2.** Quantitatively constrain the age and processes of accretion, differentiation, and thermal evolution of Mars. |
| | **C1.** Constrain the planetesimal density and type within the Mars neighborhood during Mars formation, as implied by the origin of the Mars moons. |
| | **C2.** Determine the material and impactor flux within the Mars neighborhood, throughout Mars' history, as recorded on the Mars moons. |

HSO-SAG

## Geoscience Objectives

| C1 | Characterize the composition of surface units and evaluate the diverse geologic processes and paleoenvironments that have affected the martian crust; determine the sequence and duration of geological events, and establish their contex... ...bout planet... ...decade). See ne... |
|----|------|
| C2 | Deterr... ...rmine their h... ...o major events... |
| C3 | Constrain the dynamics, structure, composition and evolution of the martian interior, to answer larger questions about planetary evolution (to be refined based on discoveries during the next decade). See next slide for additional detail. |

**Most important messages:**
1. Maximize contact time between outcrops and geologist-astronauts
2. Priorities: mobility systems, EVA time, geologic diversity, range of geologic age

HSO-SAG

# Mars Landing Site Selection

Engineering Criteria (SMD/MEPAG and HEOMD/HAT)

ISRU and Civil Engineering Objectives
ICE-WG

Scientific Objectives (SMD/MEPAG)
HSO-SAG

**GEOLOGY INPUTS**

Integration Workshop → LS/EZ Open Call → Identification of candidate EZs → **LS/EZ Workshop** *(Fall 2015)*

*Deliverables*
EZ List
MRO request
New recon data
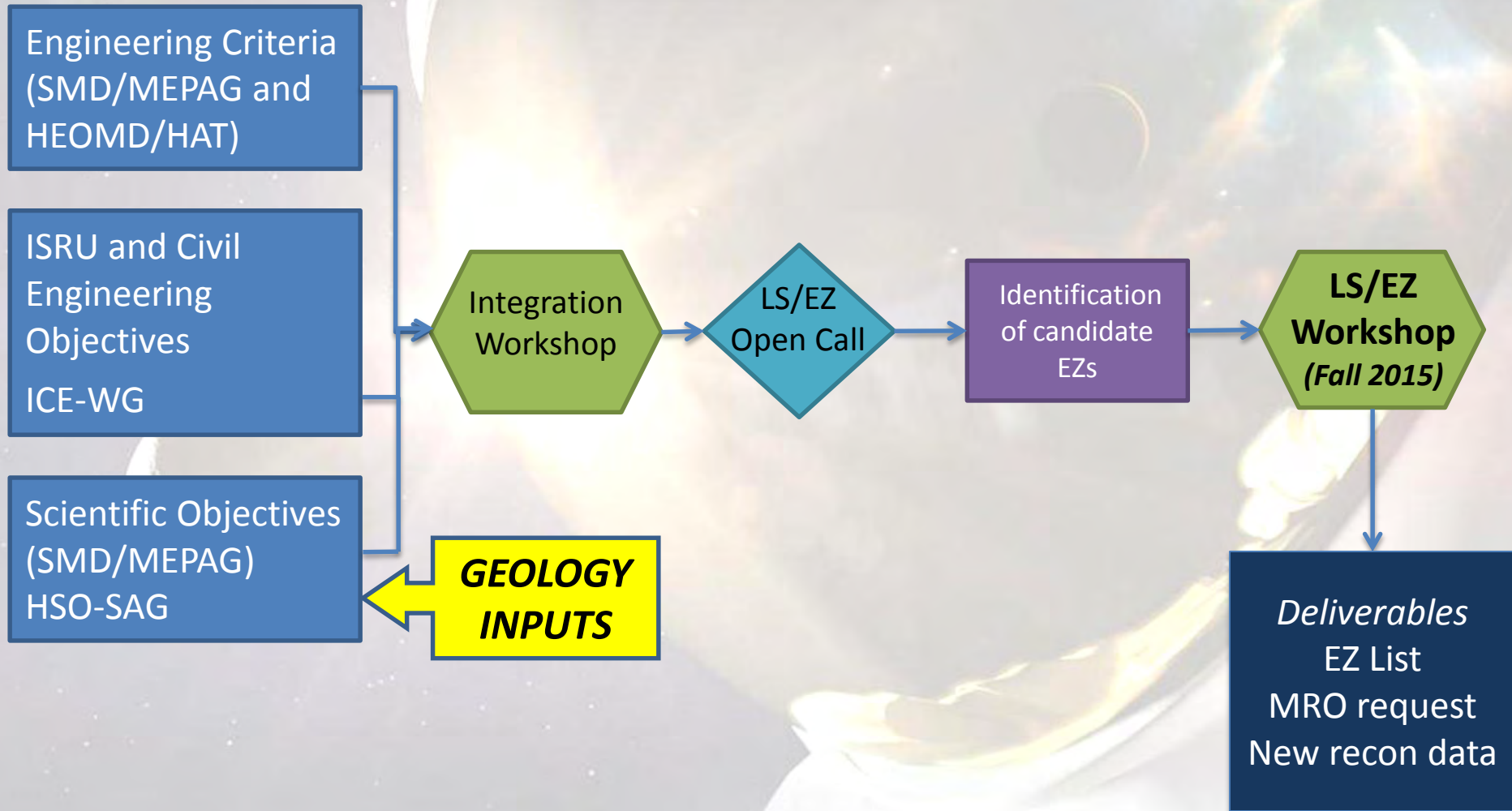
LS: Landing Site
EZ: Exploration Zone

HSO-SAG

# SBAG Goals

- **Goals and Objectives for the Exploration and Investigation of the Solar System's Small Bodies**
- *Goal 1 – Small Bodies, Big Science*
- *Goal 2 – Defend Planet Earth*
- *Goal 3 – Enable Human Exploration:* Advance our knowledge of potential destinations for human exploration within the small body 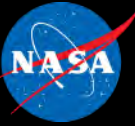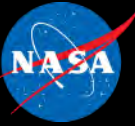population and develop an understanding of the physical properties of these objects that would enable a sustainable human presence beyond the Earth-Moon system.
  - **Objective 3.1.** Identify and characterize human mission targets.
  - **Objective 3.2.** Understand how to work on or interact with the surfaces of small bodies.
    - **e.g. Understand how to translate across the small body surface.** What are the best ways to translate for an astronaut on EVA vs. a spacecraft? Will regolith help or hinder this activity? Are there preferred locations/conditions for translation?
  - **Objective 3.3.** Understand the small body environment and its potential risk/benefit to crew, systems, and operational assets.
  - **Objective 3.4.** Evaluate and utilize the resources provided by small bodies.

http://www.lpi.usra.edu/sbag/goals/

Updated yearly (last updated March 2016)

# SBAG SKGs

- Bodies of interest: NEOs, Phobos, Deimos
- Small Body SKG categories (similar to SBAG goals)
  1. Human mission target identification (NEOs)
     - e.g. NEO rotation state (impact on crew surface activities)
  2. Understand how to work on or interact with the small body surface
     - e.g. Non-contact close proximity operations for detailed surface exploration and surveys
  3. Understand the small body environment and its potential risk/benefit to crew, systems, and operational assets
  4. Understand the small body resource potential

# Asteroid Redirect Mission: ARCM & FAST



- Asteroid Redirect Crewed Mission (ARCM)
  - ARM consists of two segments – ARRM (robotic mission) & ARCM (crewed mission)
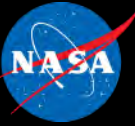  - ARCM will provide the opportunity for human explorers to work in space with asteroid material, testing the activities that would be performed and tools that would be needed for later exploration of primitive body surfaces in deep space.
- Formulation Assessment and Support Team (FAST)
  - A two-month effort that NASA chartered to provide timely inputs for ARM mission requirement formulation; consisted of members with expertise in small bodies
  - FAST answered seven groups of questions
    - Origin of 2008 EV5, Boulder Spatial and Size Distributions, Surface Geotechnical Properties, Boulder Physical Properties, Post Collection Boulder Handling, Pre-ARM Crew Mission Boulder Assessments for Crew Safety, Containment Considerations
  - A few EVA-relevant findings:
    - **Dust/Particulate Mitigation Techniques (8):** Demonstrate cleaning and dust/particulate mitigation methods and protocols for suits and EVA systems that will be brought into the crewed volume '
    - **Surface Contact Science Package (36):** Deploy a surface contact science package to investigate the surface strength, composition, and magnetic susceptibility of the target asteroid, which could help inform the final design of EVA tools and operations.
    - **Collect Samples from Boulder (38):** EVA planning to ensure the most valuable samples are collected within the EVA capabilities.
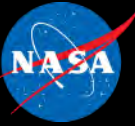
http://www.nasa.gov/feature/arm-fast
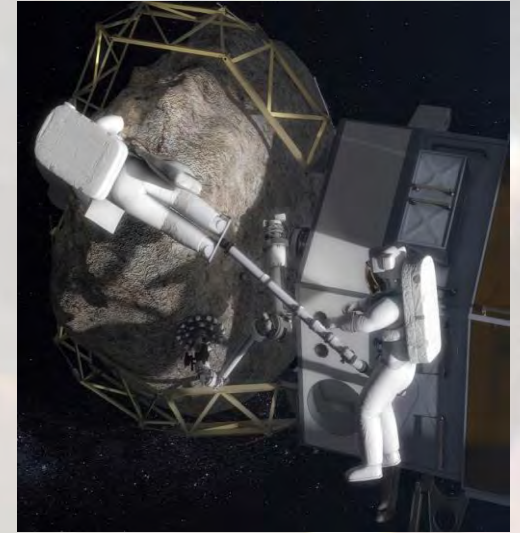
# Opportunities for Collaboration

- LPSC – Lunar and Planetary Science Conference
- AGU – American Geophysical Union
- GSA – Geological Society of America
- Annual Meeting of the AGs
- Numerous International Conferences

- SSERVI – Solar System Exploration Research Virtual Institute

- PSTAR

# Science Integration into Human Exploration

## Science Community Must Continue to Develop:

### Tools
*Instrument Development and Curation*






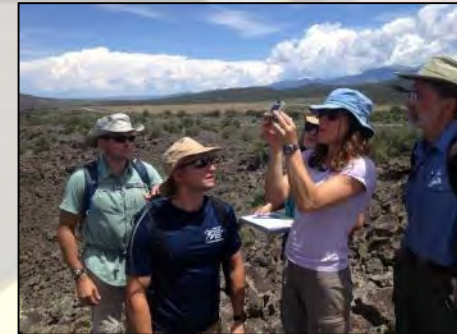
*Ex. Science and Tools
Collaboration Group*

### Techniques
*Science Operations*







### Training
*Field Training Next Generation
of Planetary Explorers*

# Analog Testing

## Apollo Surface Operations
- Exploration traverses were planned in advance using imagery gathered from precursor satellites
- Crews had significant training in geology and science tasks
- An Earth-based science team (ST) supported EVAs (Precursor plans, Feedback during EVA, and changes between EVAs)

Low communication latency (~1.25 sec OWLT)

## Mars Robotic Missions
- Remote science operations
- Instrumentation / sample selection

High communication latency for Mars (~4-22 min OWLT)

MER A - Spirit
MER B - Opportunity
MSL - Curiosity

| 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |

## NASA Extreme Environment Mission Operations
- Utilizes unique facility & environment; rapid prototyping; Evaluations of both IVA and EVA objectives

Tested-bed for a variety of communication latency for detailed EVA/Science evaluations

Science

| 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |

## Research and Technology Studies
- Utilizes terrain appropriate for geo-science tasks; Suit and robotic test-bed

Tested a variety of communication latencies for geo-science operations

Science

| 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |

## Science Field Campaigns
- Science focused
- Funded though grant programs
- Utilized as analogs

PAVILION LAKE RESEARCH PROJECT

RISE REMOTE IN SITU AND SYNCHROTRON STUDIES FOR SCIENCE AND EXPLORATION

*But more on this later…*

## Other NASA Analog Programs
- Each exploring various aspects of exploration
- Funded though grant programs
- Science focused

Test a variety of communication latencies

ISRU
HI-SEAS
BASALT RESEARCH PROJECT